Bethe-Heitler process generator

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DESY

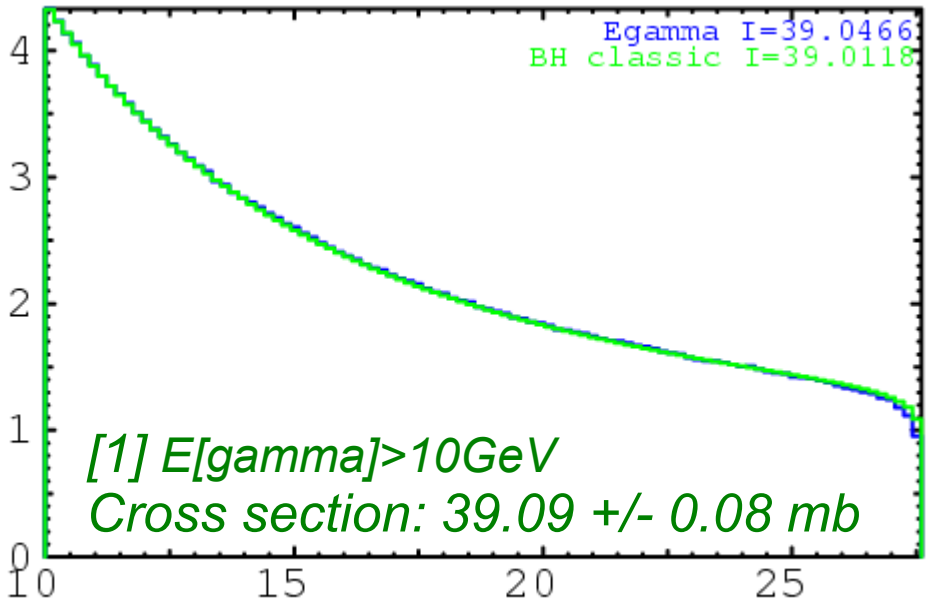
Problems from previous reports:

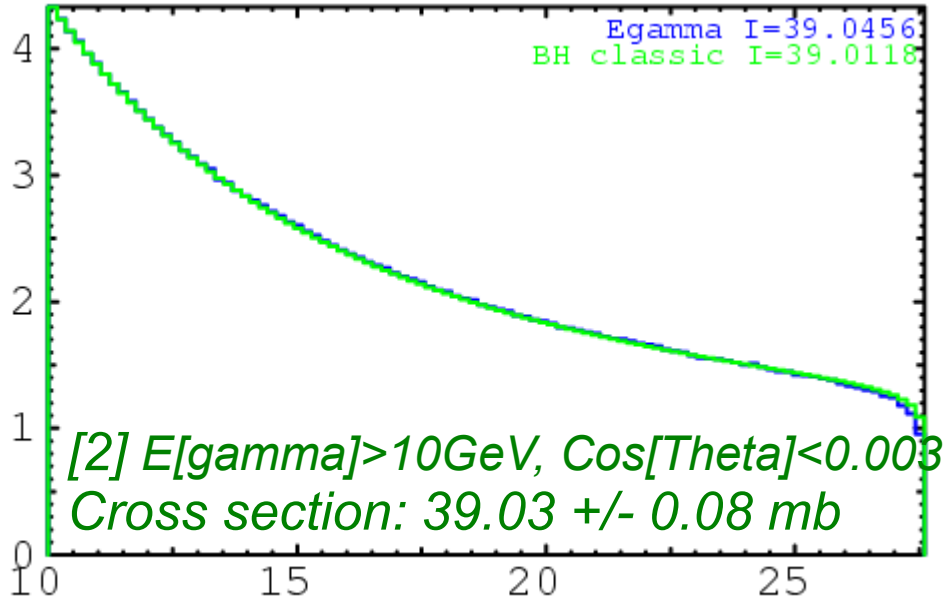
- Precision of integration not enough
  solved partially

- Sufficient discrepancy at Egamma>25GeV
  Tested with different matrix elements, and generator settings

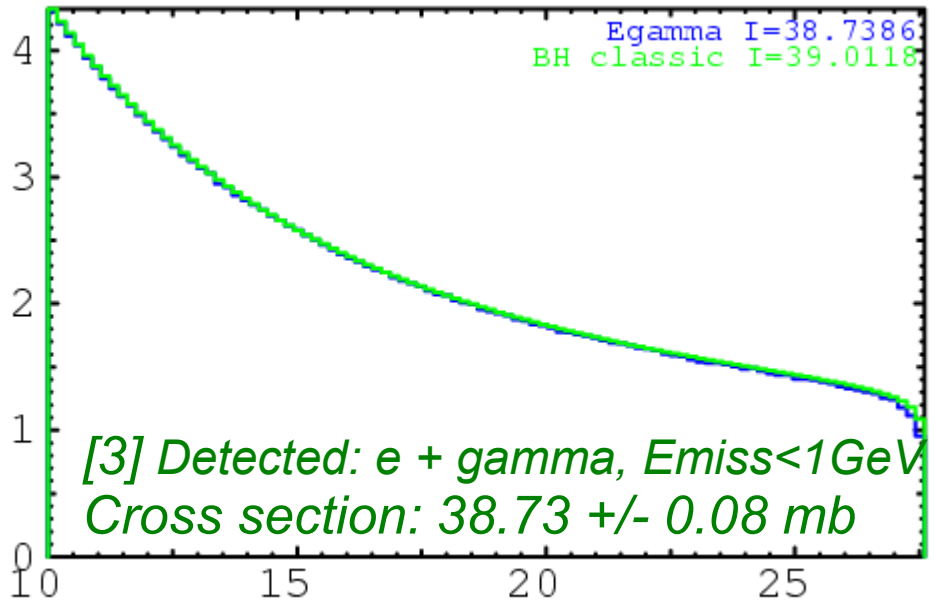
- Too slow events generation procedure
  solved: parallel generation is now available

920 GeV



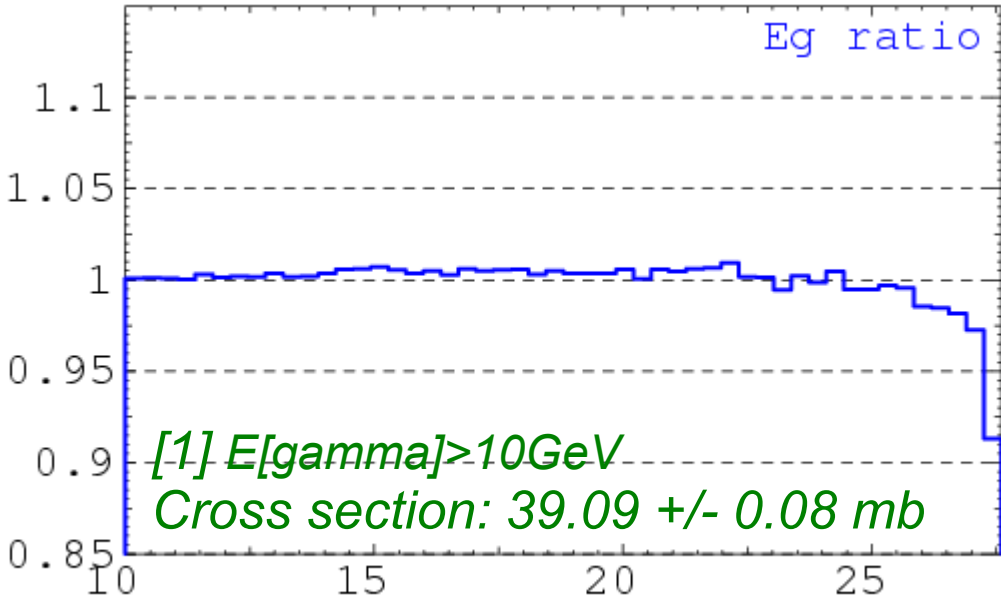


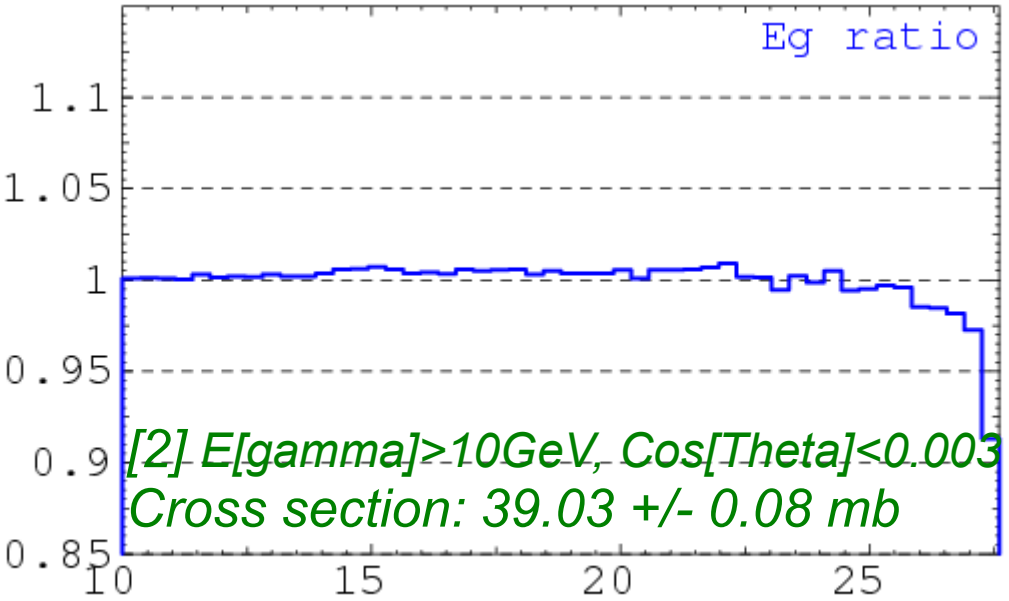
Photon energy spectrum



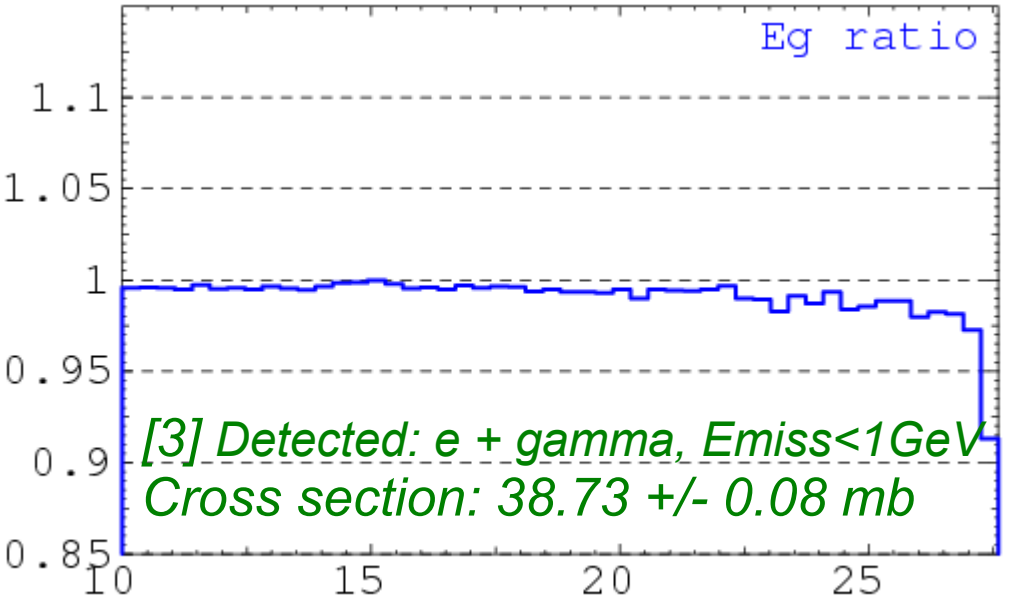
[4] E[gamma]>10GeV
Classic: 39.012 mb

920 GeV





Photon spectra ratios



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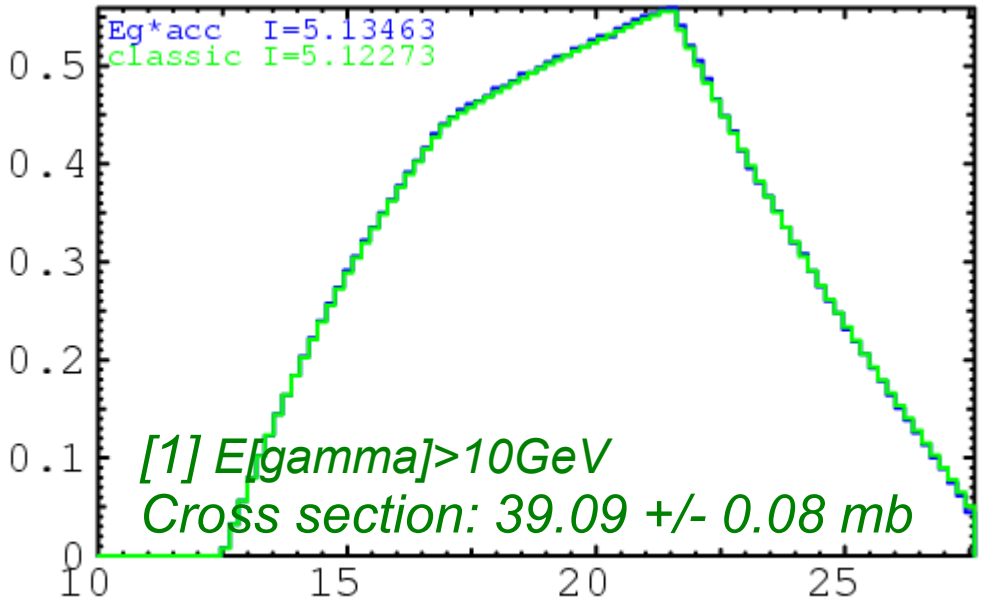
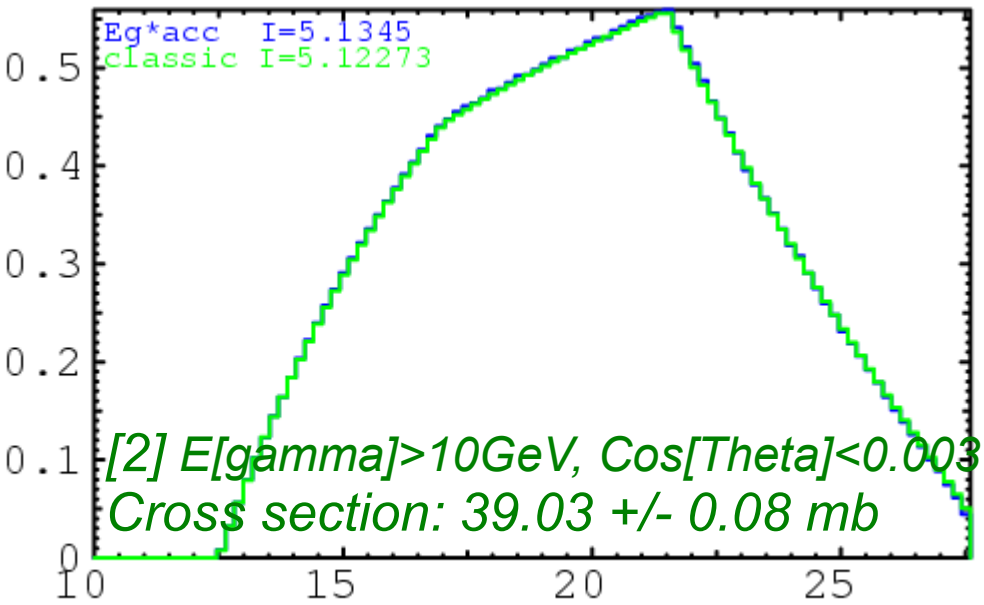
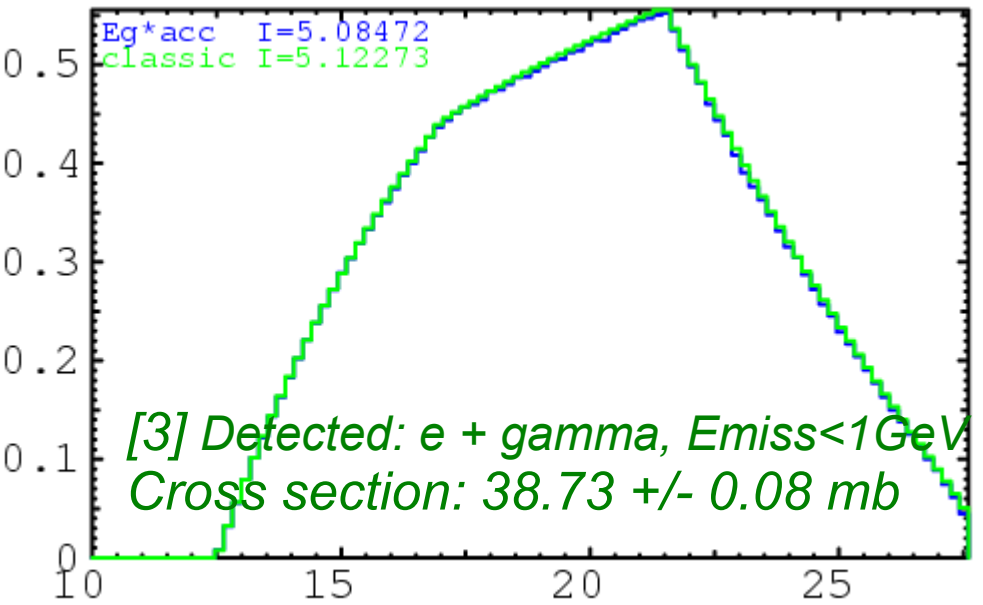


[1] E[gamma]>10GeV
Cross section: 39.09 +/- 0.08 mb



[2] E[gamma]>10GeV, Cos[Theta]<0.003
Cross section: 39.03 +/- 0.08 mb

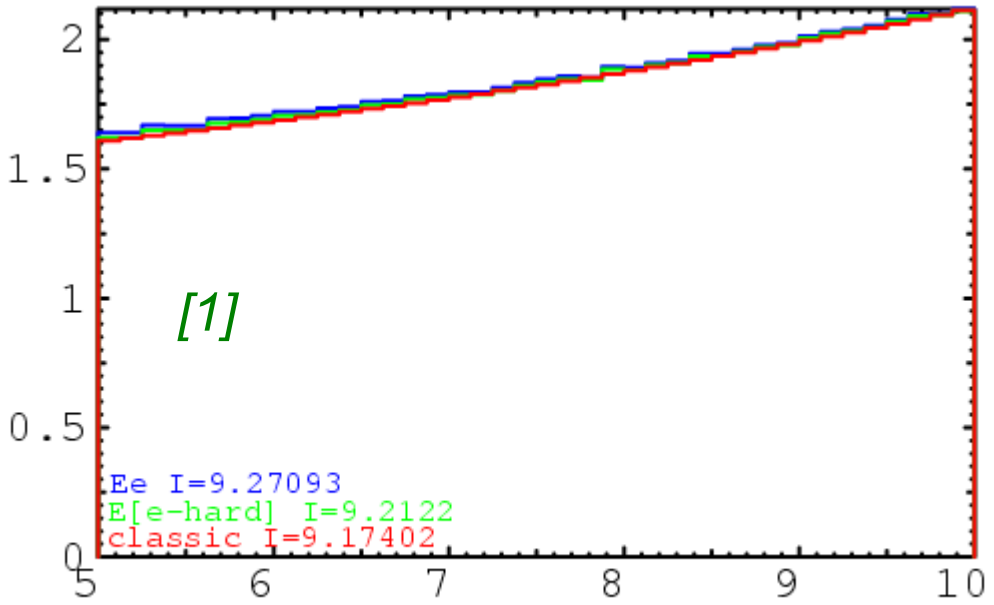
Photons accepted

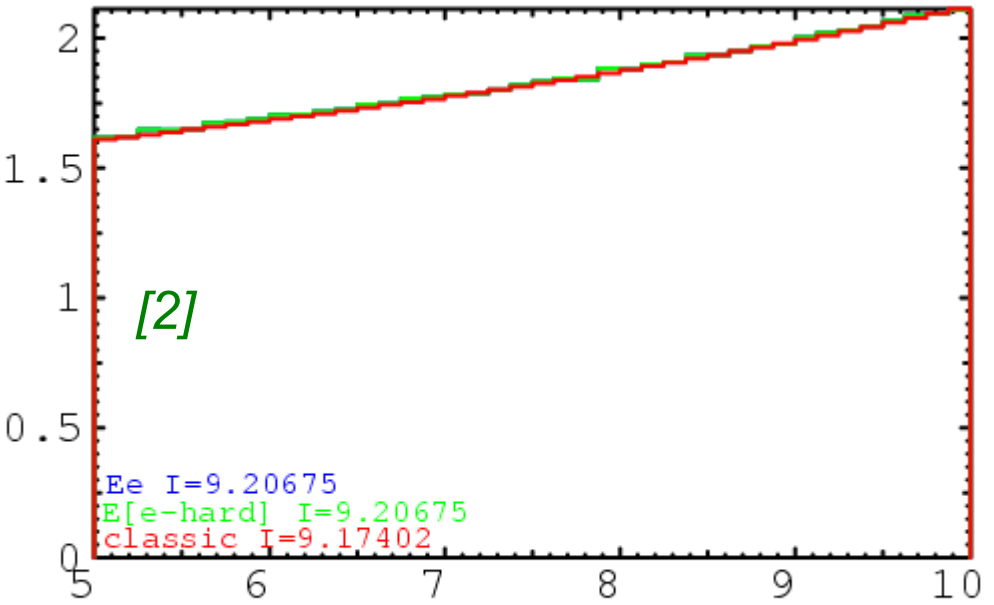


[3] Detected: e + gamma, Emiss<1GeV
Cross section: 38.73 +/- 0.08 mb

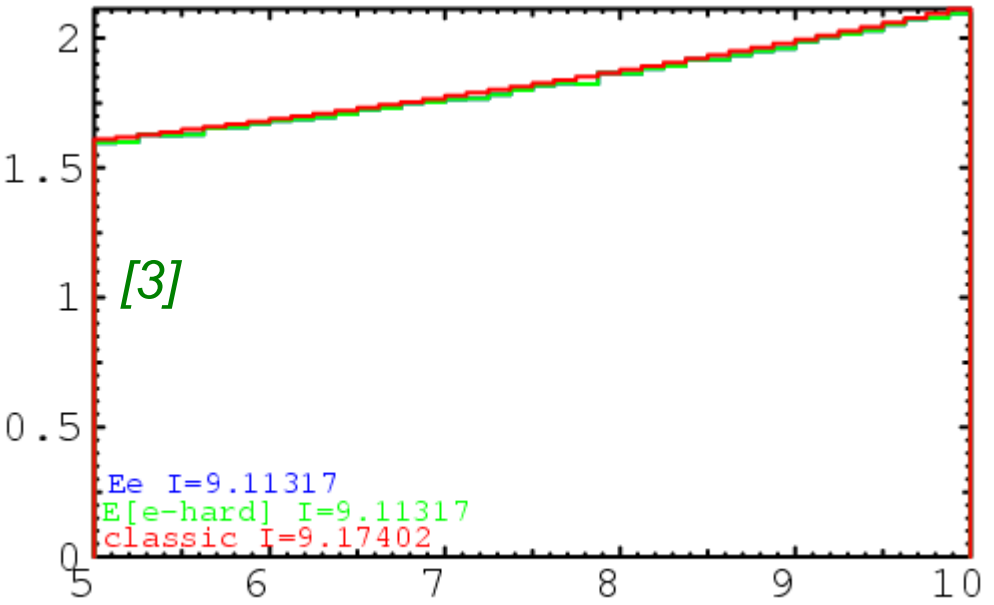
[4] E[gamma]>10GeV
Classic: 39.012 mb

920 GeV

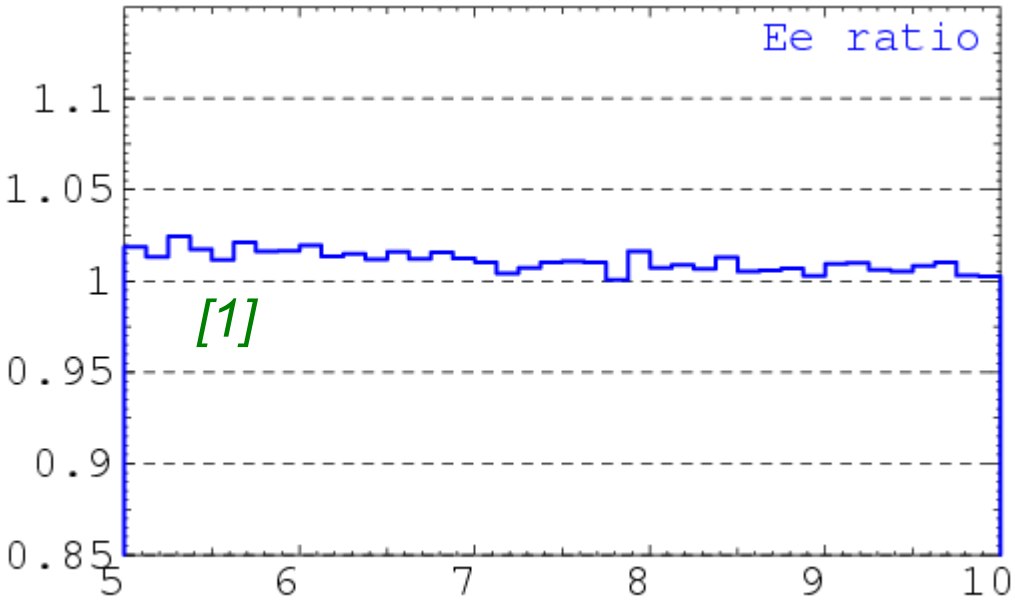


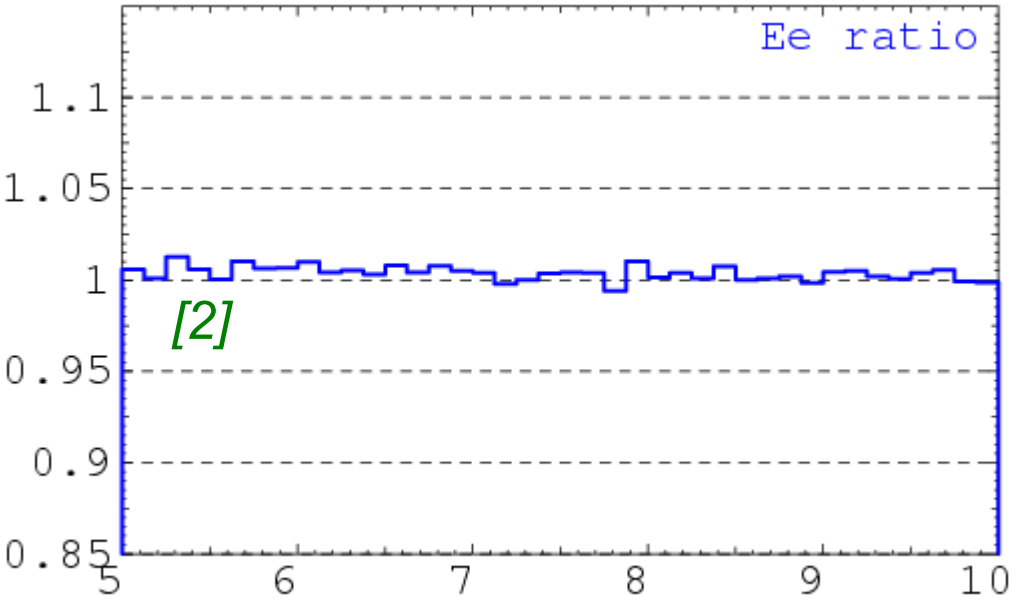


Electron energy spectrum

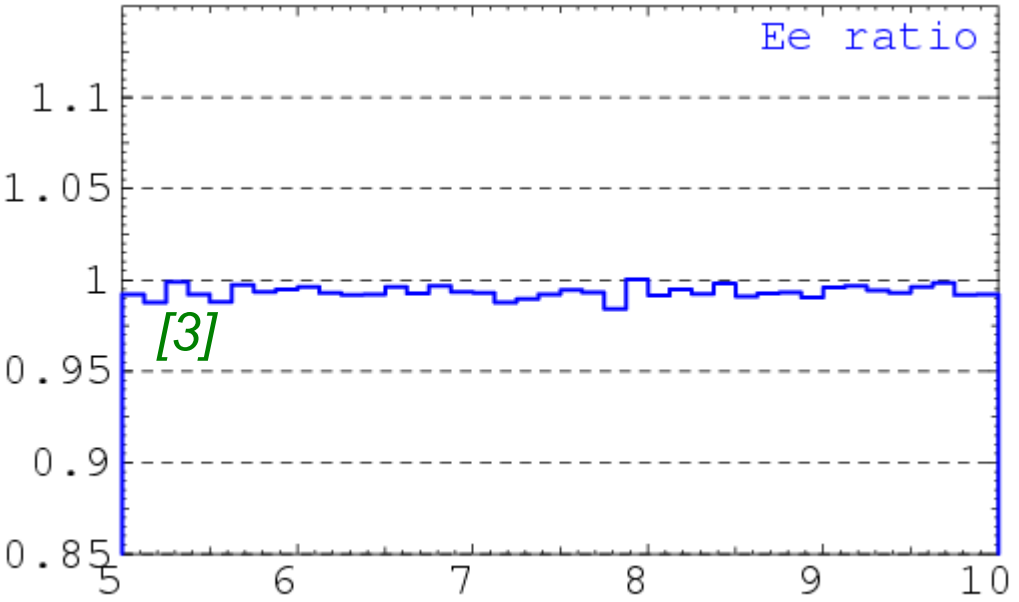


920 GeV

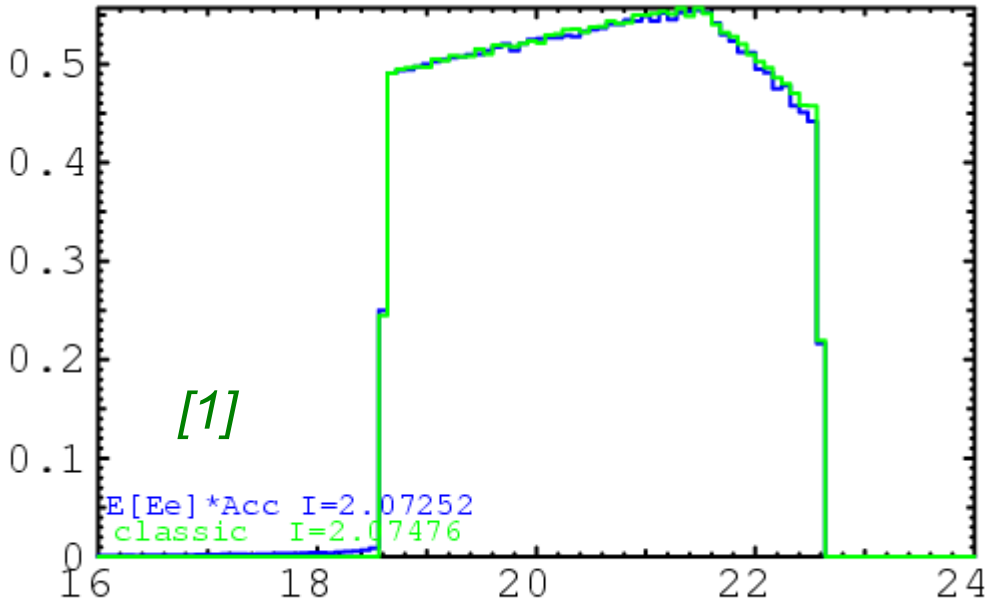


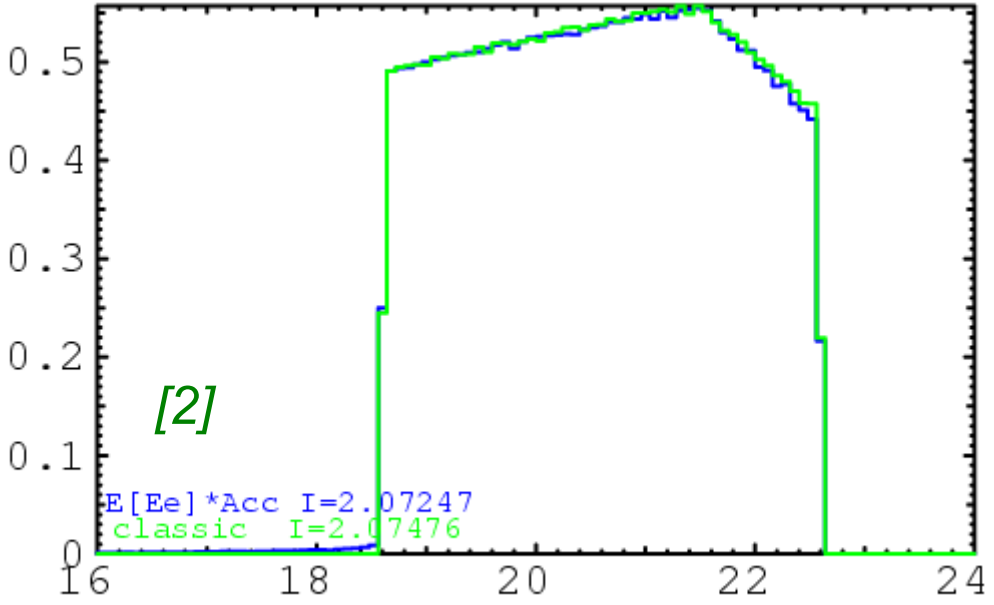


Electron spectra ratios

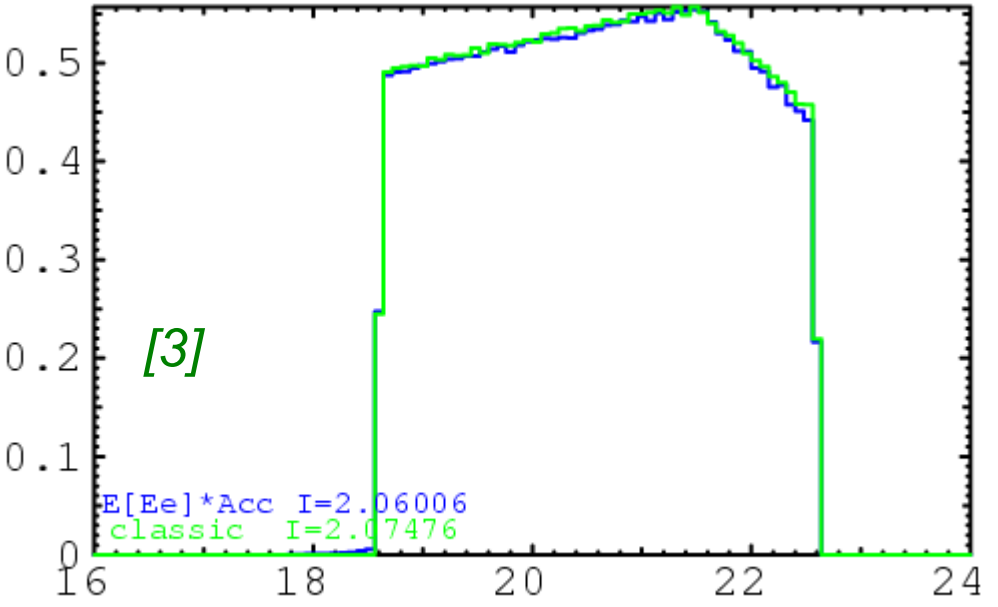


920 GeV





Photons accepted at
5GeV < E[e] < 9GeV



The plots
for other proton energies
are similar

Counter-checks made

1. Matrix element calculation
   - different matrix element representation were tested

2. Integration core
   - checked by variation of internal parameters of generator
   - checked by other integration codes (but in sub-regions only)
   - no full check with external program is available

2. Misc. checks
   - effects of histogram binning, normalization, etc.

Conclusions

1. Generator works

2. Generation is fast enough

3. The effect of RC is below the integration error in the most region

4. Discrepancy exist =>
   Full simulation of calorimeter is required to clarify the effect

Supplementary slides
(from previous talks)

Previous results

The classical Bethe-Heitler forumla is currently used:

- *H.Bethe, W.Heitler, Proc.Roy.Soc.**A146**(34)83*

$$\frac{d\sigma_{BH}}{dE_\gamma} = 4\alpha r_e^2 \frac{E_{e'}}{E_\gamma E_e}\left(\frac{E_e}{E_{e'}} + \frac{E_{e'}}{E_e} - \frac{2}{3}\right)\left(\ln\frac{4E_pE_eE_{e'}}{M_pM_eE_\gamma} - \frac{1}{2}\right)$$

$$E_\gamma + E_{e'} = E_e$$

$$d\sigma/d\Theta_\gamma \sim \Theta_\gamma/((M_e/E_e)^2 + \Theta_\gamma^2)^2$$

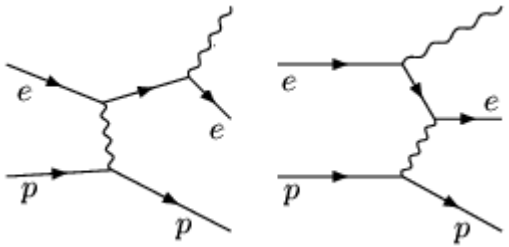
Previous higher-order effects studies:

- *K.J.F.Gaemers, M.van der Horst, Nucl.Phys.**B316**(89)269*
- *M.van der Horst, Nucl.Phys.**B347**(90)149*

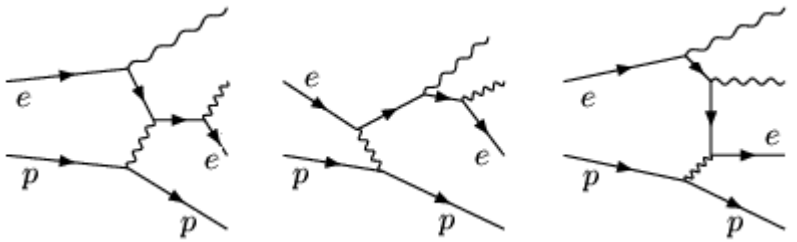
- The higher-order effects are below 1% in the region [*8 < E[γ] <14 GeV*]
- No generator was published.

The higher-order effects

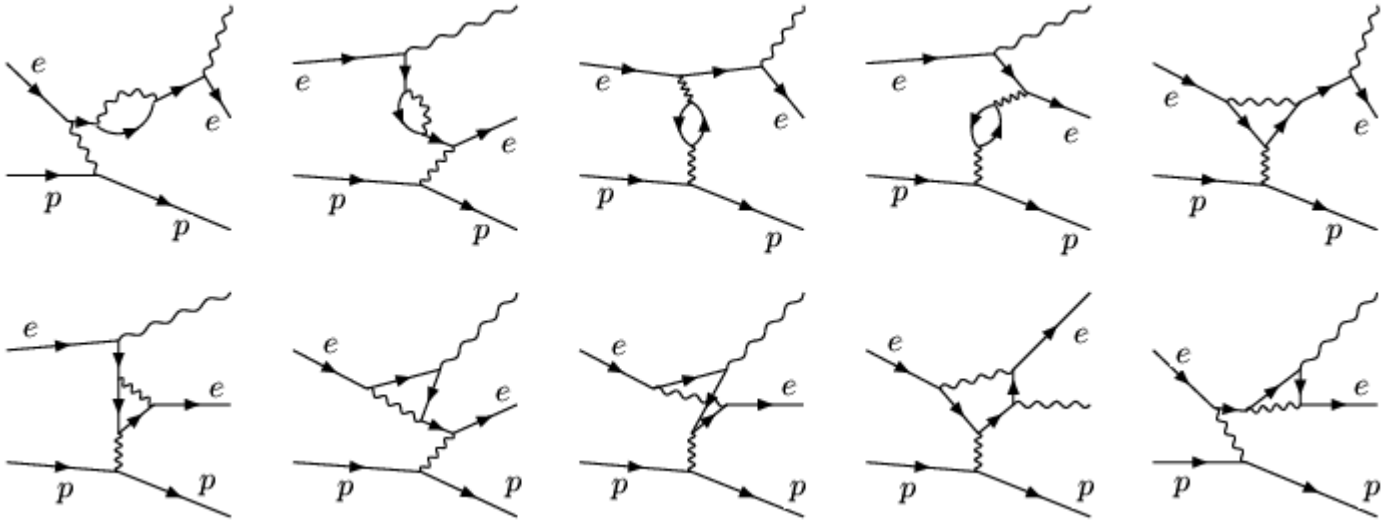
1. $pe^{\pm} \to pe^{\pm}\gamma$ including one-loop QED radiative corrections.



Tree-level diagrams

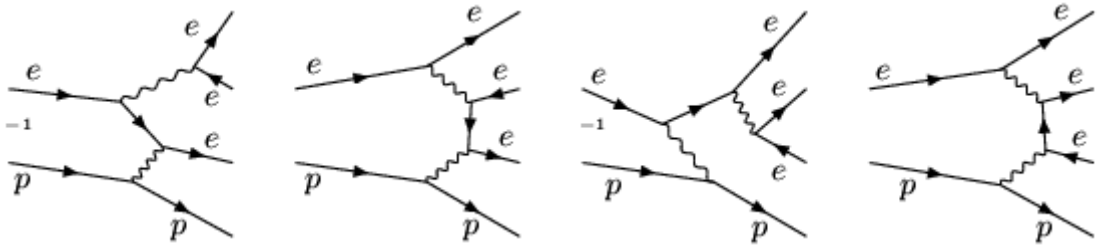


Real photon emission diagrams



Loop diagrams

2. $pe^{\pm} \to pe^{\pm}e^{+}e^{-}$ with at least one electron detected.



+ crossings

Numerical stability & technical details

1. $pe^{\pm} \to pe^{\pm}\gamma$

$$Q^2_{min} \approx \frac{m_e^4 M_p^2}{s^2 (E_{el}/E_{min} - 1)^2} \approx 3 * 10^{-25}\, GeV^2$$

$$Q^2_{max} \approx s - m_e^2 - M_p^2 \approx 10^5\, GeV^2$$

$3 * 10^{-25} < Q^2 < 10^5$ → *30 digits!*

2. $pe^{\pm} \to pe^{\pm}e^+e^-$

$$Q^2_{min} \approx \frac{64\, m_e^4 M_p^2}{s^2} = 4 * 10^{-22}$$

$$Q^2_{max} \approx s - m_e^2 - M_p^2 \approx 10^5\, GeV^2$$

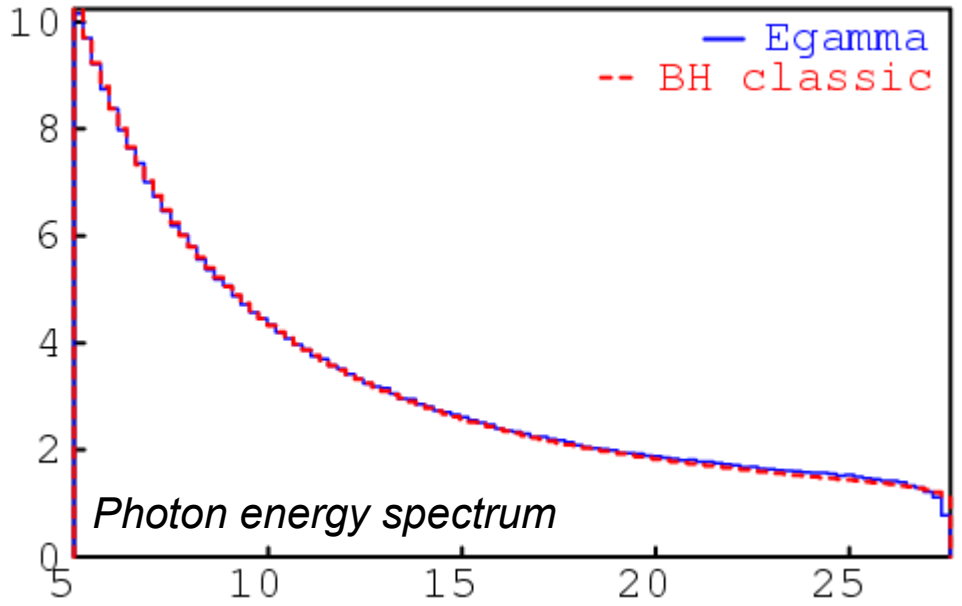
$4 * 10^{-22} < Q^2 < 10^5$ → *26 digits!*

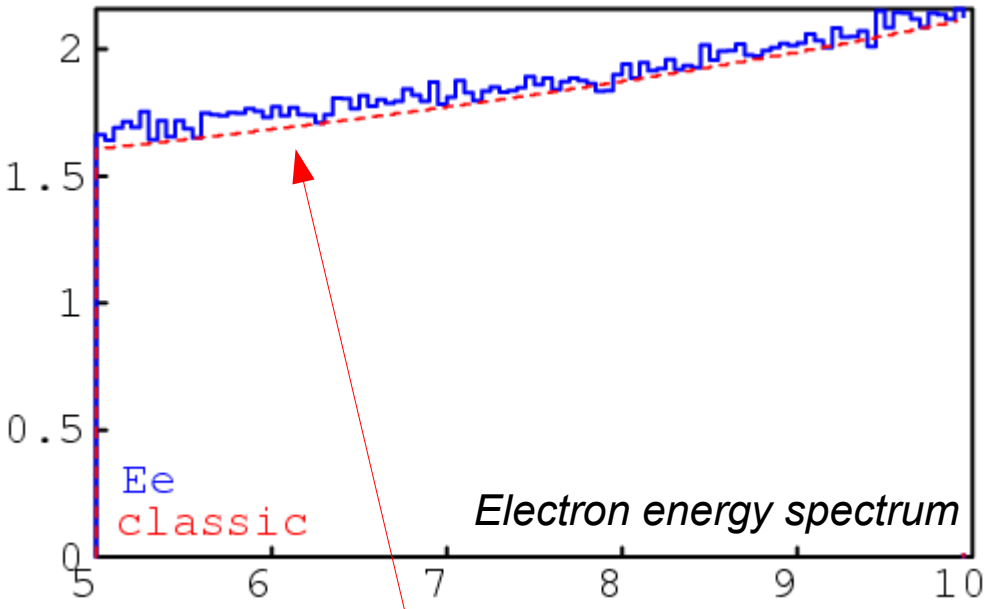
No standard generator can be used!

- GenLite generator created
  - ***good for peaking functions***
  - ***deals correctly with small Q2 values***
  - ***avoids extra Lorentz transformations***
  - ***scalar couplings produced by generator (not from generated vectors)***

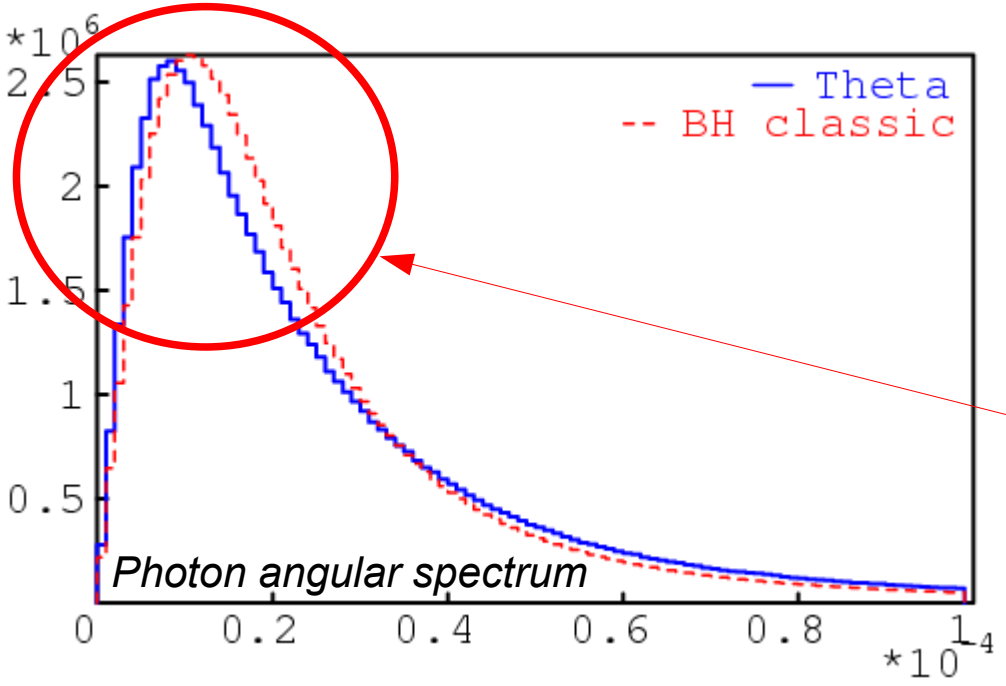
- Diagrams + analytic calculations: by ALHEP [http://*cern.ch/~makarenko/alhep*]
- Loop integrals: by LoopTools [T. Hahn, Nucl.Phys.Proc.Suppl. 89(2000) 231]
- Bremsstrahlung IR-term separation: phase space slicing at E < 10^-6 GeV
- Collinear divergences: kept by generator.
- High-precision floating point: by QD [Y.Hida, Xi.S.Li, D.H.Bailey, Tech. Report LBNL-46996]

Photon / electron spectra





The difference appear in electron energy spectrum



The angular peak is at
~ 0.015 mrad
The divergence of the electron beam:
~ 0.23 mrad (horizontal)
~ 0.07 mrad (vertical).

Cross sections & conclusions:

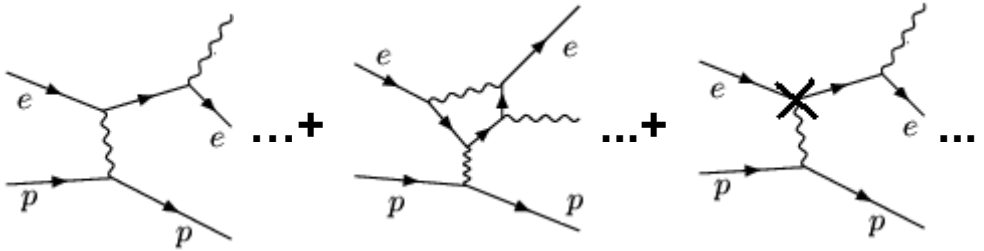
1. Born-level process

72.47 ± 0.05 mb

E[any γ]>5GeV (classical: 72.49 mb)

2. Including one-loop radiative correction

2.1.Born process + loops + counter-terms + soft photons **69.9 ± 0.2 mb**



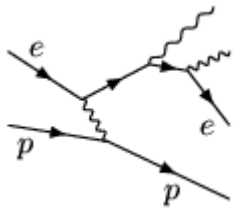
72.8 ± 0.3 mb

2.2. Radiative photons **2.9 ± 0.2 mb**

E[any γ]>5GeV

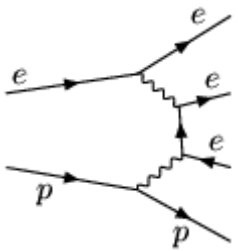
0.179 ± 0.006 mb

E[both γ]>5GeV



3. Electron-positron pair production: **0.118 ± 0.008 mb**

5GeV < E[any e] < 10 GeV



Final generator uses pre-integrated grid for all sub-processes and generates mixed events.

Generation performance: 10^5 events/hr

To be improved